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RECOLORING FORMULATIONS FOR SPECIAL CAMOUFLAGE APPLICATIONS

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B.A. Natsios, A.O. Ramsley, A. Merola

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This report describes research on two series of pigment formulations that closely duplicate the U.S. Army 4-color patterned clothing intended for verdant terrains. One of the series is durable; the other is removable. Composition, reflectance data and photographs illustrate the end results. Use of monotone olive green load-carrying equipment with camouflage patterned clothing is obviously incompatible with the objectives of personal camouflage. Economic factors preclude patterning the fabrics and webbings prior to fabrication of pouches, belts and other items of equipment. The alternative is to provide

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20. troops with the means for recoloring the equipment themselves to provide self-consistent camouflage according to the characteristics of specific terrains.

PREFACE

The work reported is the culmination of laboratory work performed intermittently over a number of years during periods of changing emphasis. The more recent efforts reported herein were initiated mainly in response to an IPR for a Camouflage Test to be performed in 1974 in conjunction with MASSTER. A draft proposed letter of Agreement has been forwarded to the US Army Infantry Center at their request for a squad sized kit to incorporate a series of variously colored formulations.

The writers wish to acknowledge the contributions of Mr. Frank J. Rizzo, former Chief, Textile Research and Engineering Division for the impetus he provided in initiating the work and the helpful guidance he provided during early stages of the research. We also greatefully acknowledge the helpful comments, assistance in evaluation and the color photography provided by Mr. William B. Bushnell, one of our colleagues in the Countersurveillance Section.

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RECOLORING FORMULATIONS FOR SPECIAL CAMOUFLAGE APPLICATIONS

1. Introduction.

The several components of the soldier's load-carrying equipment are made of a variety of materials ranging from cotton or nylon duck and webbing to plastic aluminum and steel. For reasons of economy these are procured in only two colors, olive green for the textile components, and a lusterless black for the metal and plastic components. These colors have been standardized in appropriate specifications.

These colors are appropriate for use with the monotone Olive Green 107 uniforms in certain combat environments. Use of a monotone olive green load-carrying system with camouflage patterned clothing, however, is obviously inconsistent regardless of terrain. Compatibility of a clothing and personal equipment system with camouflage objectives requires a means of providing camouflage patterns for the load-carrying sub system. The nature of the problem is illustrated in Figure 1.

Figure 1. Monotone Load Carrying Equipment Worn with 4-Color Patterned Clothing

One approach to the problem is to print camouflage patterns on the fabrics from which the equipment is made. A minimum of three patterns (verdant, arid, snow) would be required, and at least six different webbings and fabrics are involved. An alternative approach is to provide an individual soldier with the means to recolor his equipment himself in accordance with his own perception of local camouflage requirements. The advantages of the second approach are two fold; economy and camouflage adaptability. To meet this apparent need, research has been conducted preliminary to the development of practical, field-applicable textile recoloring formulations.

With practicality in the forefront, the following objectives served as guidance to the research effort:

a. Maximum convenience and ease of application by troops with minimum impairment of personal or item function.

b. Camouflage effectiveness to observation by unaided vision, passive night vision devices, and photography. These techniques cover the visible and near-infrared regions of the spectrum to about 900 nm.

c. Minimum complications in disposal of packaging and ancillary components.

d. Minimum adverse impact on the environment.

With these objectives in mind the approach chosen was one that focussed on use of disposable brushes for application. Both the patterns and the items are too small for wide-spread use of spray equipment in a tactical setting. If circumstances warranted use of such equipment, however, appropriate dilution of the formulations would permit their use. No recent efforts have considered use of spray cans that superficially appear so convenient. This decision was based primarily on factors related to storageability, cost, and disposal. Moreover, it is inappropriate to initiate development of spray can formulations in the midst of controversy over the environmental impact of halocarbon propellants.

2. Formulations.

Over the years combat officers and others have expressed two somewhat divergent desires. Some have preferred durable colorant formulations with maximum adhesion; i.e., maximum resistance to abrasion and other use factors. Once applied, these formulations can be removed only with difficulty. Others have expressed a preference for formulations that are relatively easy to remove in the likely event that camouflage needs were to change, and a different color scheme would then be more appropriate. During use, however, this second formulation must be resistant to leaching by water and to abrasion.

To respond to these two divergent views, two compositions have been formulated these are referred to as durable and removable. To correlate with efforts to provide broad-band camouflage (includes near-infrared), colorants were selected to provide appropriate reflectances from 400 to 900 nm.

a. Durable Textile Recoloring Formulation.

An earlier version of this formulation was attempted using a polyurethane binder. It was found that use of this binder and its necessary additives led to excessive gloss and stiffness when applied to pouches, packs, and other components. To reduce gloss and improve flexibility of recolored items, colorant formulations were developed that were based on a chlorinated rubber binder. Table 1 summarizes the compositions for four colors of durable textile recoloring formulations. These four colors are intended to reproduce the four colors of the 1948 US Army Camouflage Pattern that is authorized for use in the tropical uniform.

From Table 1 it is seen that the durable formulations are organic-solvent-based. They may be thinned and be removed with small difficulty from fabric by non polar solvents such as dry cleaning solvents or gasoline, which may also be used for cleaning brushes. It is not recommended, however, that dry cleaning equipment be used, because the process is likely to contaminate the equipment, and before it could be used for its more conventional purposes, the equipment would require thorough cleaning.

Figure 2 presents reflectance curves from 380 to 1000 nm for the four colors applied to a nylon duck such as that used for the pack. These curves have been integrated through the visible spectrum with respect to the C.I.E. 1931 Standard Observer and Source C to obtain colorimetric definition of the colors. The curves have also been integrated by the method set forth in MIL-E-52798, Enamel, Modified Alkyd, Camouflage, Lusterless, to obtain an IR/Red ratio. The computational data are listed in Table 2.

b. Removable Textile Recoloring Formulations.

Recognizing the desire for a formulation that could be applied in the field as needed and then removed when the particular need no longer existed, a removable composition was also formulated. It is intended that the formulation be removable by standard methods in a field laundry unit. For this to be possible, it was necessary for the formulation to be water based, rather than organic solvent based.

In earlier efforts, successful removal of the formulations was not possible for two reasons: the particle size of some of the pigments used was too small, and the binders themselves may not have been labile enough. The pigments needed to achieve proper infrared characteristics evidently do not adhere as firmly to the fibrous substrate as some of those used previously. Also, better binders are now available. For these reasons it is believed that removability of the present formulation is adequate. Removal was accomplished in standard laundry equipment using standard field methods that are alkaline.

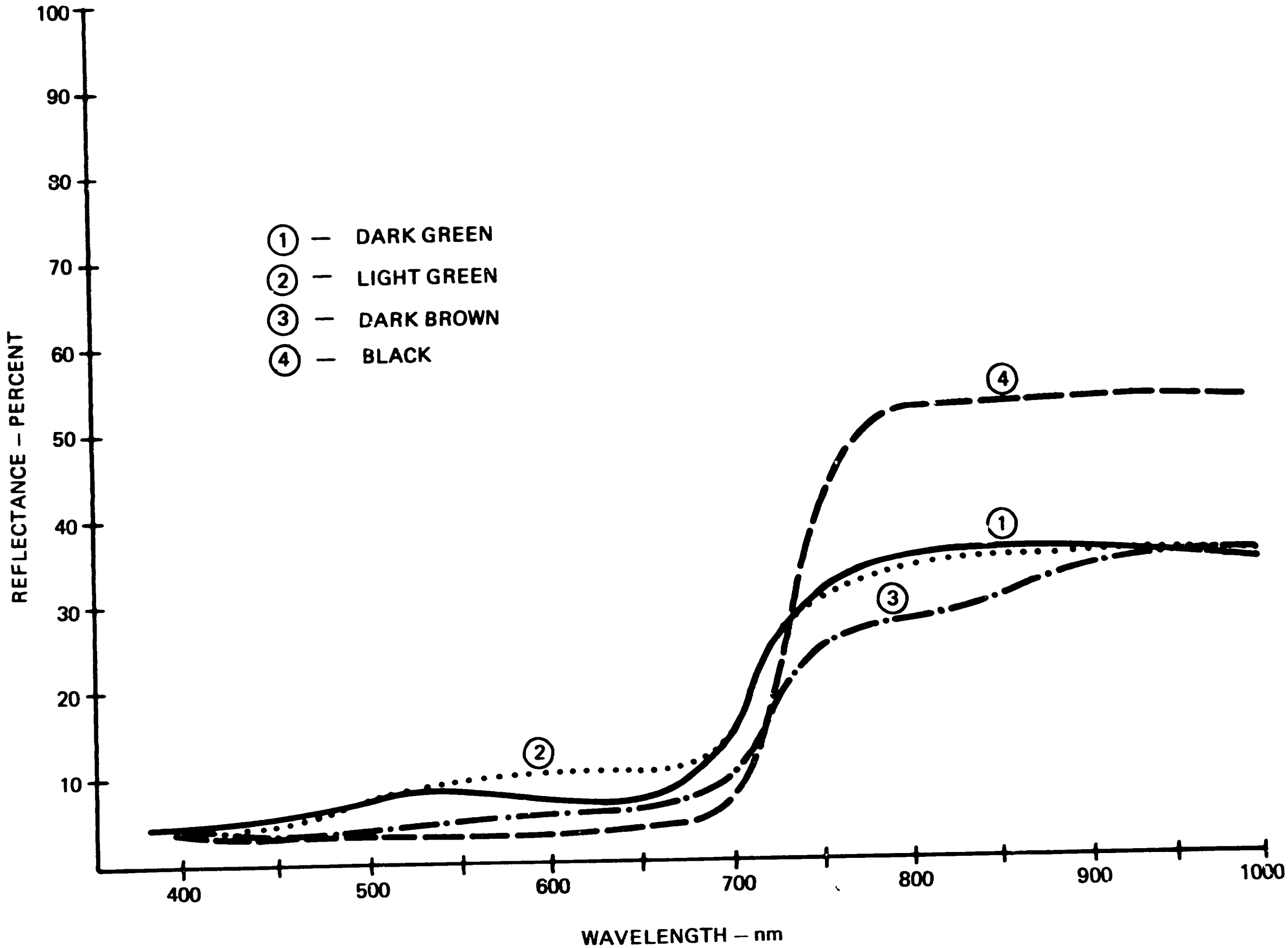

Figure 2. Reflectance Curves for Durable Recoloring Formulations Applied to Nylon Duck.

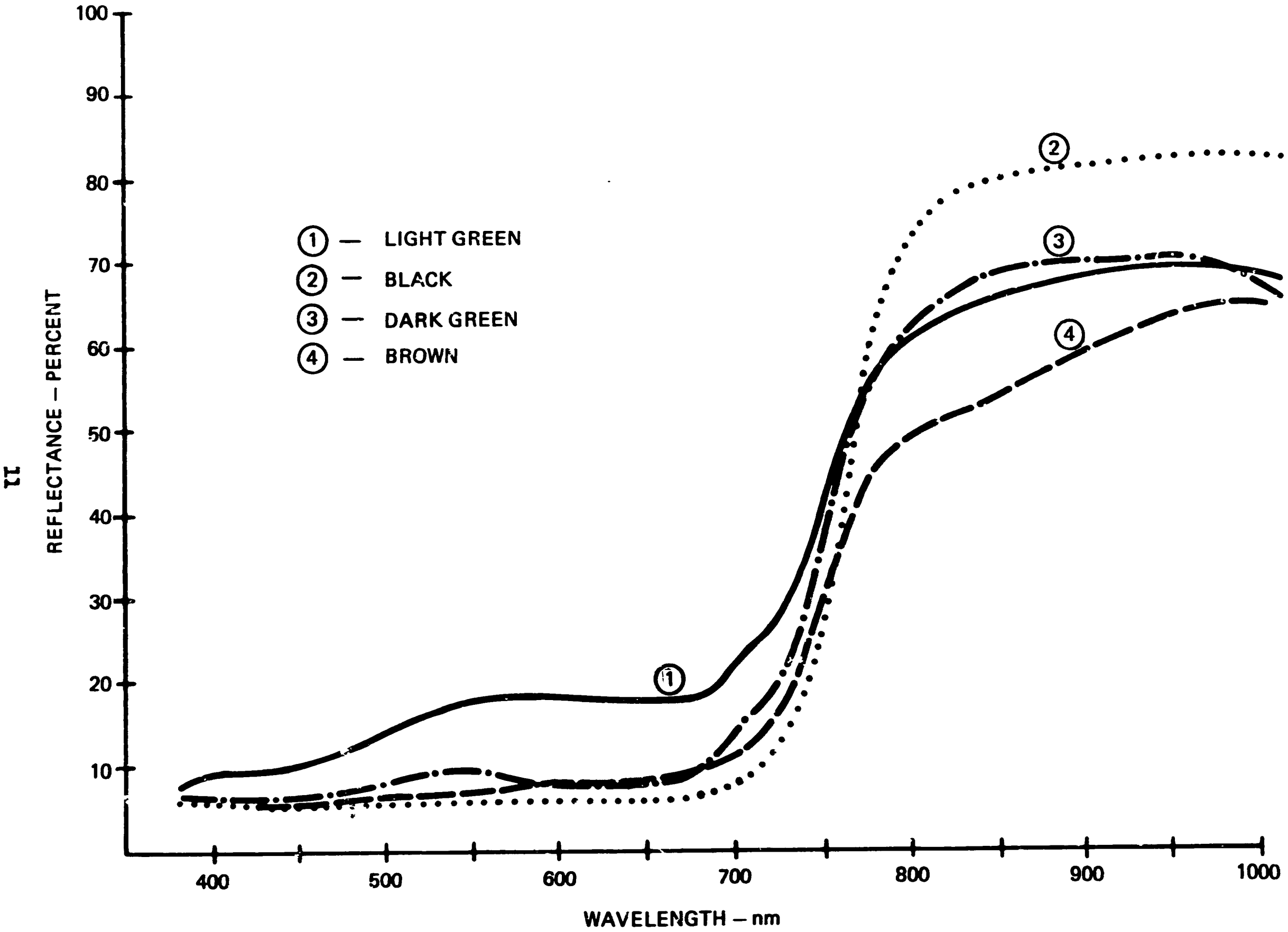

Figure 3. Reflectance Curves for Removable Reccloring Formulations Applied to Nylon Duck.

TABLE 1. COMPOSITION OF DURABLE TEXTILE RECOLORING FORMULATIONS
(parts by weight)

Ingredients	Trade Name*	Dark Green	Light Green	Dark Brown	Black
Green	K-639 (1)	6.4	6.5		
Yellow	V-9112 (1)	trace	6.5	4.9	
Brown	F-6111 (1)		trace	4.8	
Rutile Titanium Dioxide	R-900 (2)	trace			
Antimony Sulfide	RM137 (1)	5.9		3.7	13.4
Chlorinated Rubber 10 cps	Parlon S-10 (3)	6.7	6.7	6.7	6.7
Chlorinated Paraffin Plasticizer	Chlorowax 40 (4)	9.9	9.9	9.9	9.9
Organic Thixotropic Thickener	Thixatrol ST (5)	0.7	0.7	0.7	0.7
Epoxy Resin, (185-192 Epox. Equiv)	Epon 828 (6)	0.3	0.3	0.3	0.3
n-Butyl Acetate	(7)	20.0	20.0	20.0	20.0
Epichlorhydrin	(7)	0.1	0.1	0.1	0.1
Totals		50.0	50.7	51.1	51.1

* Note: Numbers in parentheses refer to commercial sources of materials. These sources are listed in Table 6.

TABLE 2. OVERCOLORING COMPOUND-DURABLE

	x	y	Y	RED	IR	RATIO
Light Green	0.3623	0.3806	9.39	10.97	31.18	2.84
Dark Green	0.3270	0.3673	7.84	7.27	32.12	4.42
Dark Brown	0.3493	0.3499	5.98	7.30	26.71	3.66
Black	0.3052	0.3117	4.29	4.47	45.48	10.17

Figure 3 illustrates the reflectance curves for the four colors from 380 to 1000 nm when applied to nylon duck. Computational data for the removable formulation, obtained as for Table 2, are given in Table 3. Figure 4 and Table 5 show similar data for specimens after removal of the formulations. Table 5 summarizes the compositions for the four colors of the removable formulations.

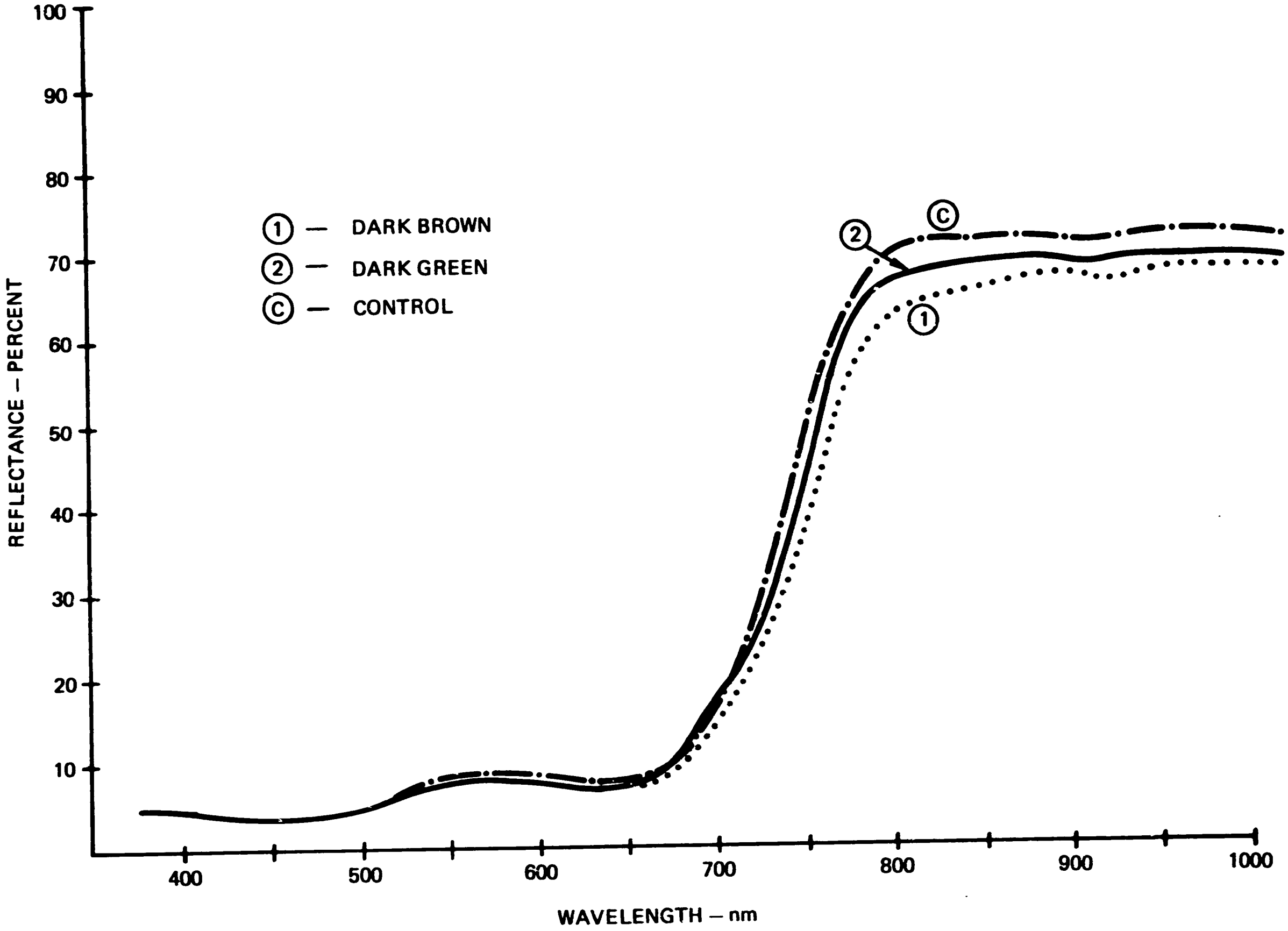

Figure 4. Reflectance Curves of Nylon Duck after Removal of Removable Recoloring Formulations.

TABLE 3. REMOVABLE OVERCOLORING COMPOUND

OVER NYLON PACK

	x	y	Y	RED	IR	RATIO
Light Green	0.3488	0.3670	16.74	17.52	54.01	3.08
Dark Green	0.3244	0.3597	8.68	8.11	53.07	6.54
Dark Brown	0.3438	0.3461	7.67	9.06	42.36	4.67
Black	0.3055	0.3096	6.14	6.23	57.23	9.20

TABLE 4. NYLON PACK FABRIC AFTER REMOVAL OF

OVERCOLORING COMPOUND

	x	y	Y	RED	IR	RATIO
Substrate	0.3624	0.3886	8.02	8.53	60.58	7.10
*Light Green	0.3586	0.3789	7.09	7.37	56.40	7.65
Dark Green	0.3551	0.3845	7.14	7.86	56.70	7.21
Dark Brown	0.3564	0.3767	6.85	7.22	54.25	7.51
*Black	0.3507	0.3697	6.40	7.17	58.95	8.22

*Curves for Light Green and Black areas after removal are too close to those illustrated for useful presentation in Figure 4.

TABLE 5. COMPOSITION OF REMOVABIE TEXTILE RECOLORING FORMULATIONS
(parts by weight)

Ingredients	Trade Name*	Dark Green	Light Green	Brown	Black
Green	K-639 (1)	7.7	3.3		
Yellow	V-9112 (1)	1.6	4.2	5.6	
Brown	F-6111 (1)		trace	2.4	
Rutile Titanium Dioxide	R-900 (2)		1.9		
Antimony Sulfide	RM137 (1)	0.8	trace	2.2	10.7
Turquoise	K-1607 (1)	0.7			
Water		28.5	28.5	28.5	28.5
Polyvinyl Acetate Copolymer	Gelva C-5V-10 (8)	7.8	7.8	7.8	7.8
Dispersing Agent	Tamol 850 (10)	0.5	0.5	0.5	0.5
Tricresyl Phosphate	TCP (8)	3.6	3.6	3.6	3.6
Nonyl Phenyl Ethylene Oxide	Igepal CO-630 (9)	0.1	0.1	0.1	0.1
Hydroxyethyl Cellulose	Cellusize QP-4400 (7)	0.1	0.1	0.1	0.1
Defoamer	Foamkill 639 (11)	0.1	0.1	0.1	0.1
26° Be. Ammonia		0.5	0.5	0.5	0.5
Totals		52.0	50.6	51.4	51.9

*Note: Numbers in parentheses refer to commercial sources of materials. These sources are listed in Table 6.

TABLE 6. SOURCES FOR INGREDIENTS IN TABLES 1 and 5.

(1) Ferro Corporation

(2) E. I. duPont de Nemours

(3) Hercules, Inc.

(4) Diamond Shamrock

(5) Baker Castor Oil

(6) Shell Chemical Company

(7) Union Carbide Corporation

(8) Monsanto Chemical Corporation

(9) G.A.F. Corporation

(10) Rohm & Haas

(11) Crucible Chemical Company

3. Evaluation.

a. Durable Formulations.

The four colors of the durable series of formulations were applied by paintbrush to a set of nylon load-carrying equipment in a pattern resembling the 4-color camouflage pattern for verdant terrains. Figure 5 is a close-up view to illustrate this application; Figure 6, at longer range, illustrates the overall effect when used as part of a personal equipment system.

The objectives stated above were generally reached with a few notable but minor exceptions. When applied as a single coating to cotton duck, the gloss remained low. When applied to nylon, however, or when multiple layers were applied, the gloss was judged excessive. The multiple layers usually occurred when adjacent areas of a camouflage pattern overlapped. When applied to nylon at normal laboratory temperatures (20-25° C) by brushing, the durable formulation was a bit too viscous. Addition of about 10 per cent solvent (n-butyl acetate) facilitated the application.

b. Removable Formulations.

Both the initial adhesion and subsequent removability of these formulations were good when applied to cotton fabrics. When applied to the nylon packs, which are water repellent, adhesion was poor and the colorant formulation flaked off easily when flexed and abrades as would occur in use.

Figure 5. Close-up View of Patterned Load-Carrying Equipment

Figure 6. View of Patterned Load-Carrying Equipment Worn with 4-Color Verdant Patterned Clothing

As may be noted in Table 2, the removable formulations did not contain a mildewcide. When partially used cans of compound were reclosed and stored, a growth of what appeared to be aspergillus niger took place. Within three months the remaining contents were useless.

Some of the cans that had not previously been opened developed a strong odor of hydrogen sulfide, some time within six months. It was observed that the intensity of odor appeared to be in proportion to the amounts of antimony sulfide used in the formulations. Thus, the black and brown colors were much more offensive than the light or dark green colors.

4. Discussion of Future Work

Despite their faults, both formulations represent considerable progress over previous efforts. Of the above cited defects, only one appears to be difficult to overcome; increasing the adhesion of the water-based removable formulations to water-repellent fabrics without impairment of the water repellency of the item. Adding wetting agents to the mixture may impair subsequent water resistance. Replacing some or all of the water with a volatile solvent of lower polarity and surface tension may be a better approach that is being investigated. Addition of a colorless fungicide should pose no problems.

Table 7 shows recommended formulations for four colors in the series of durable textile recoloring compounds. From this it is seen that several changes in composition are proposed.

a. About ten per cent of a flatting agent has been added to reduce gloss.

b. As a precaution, a mildewcide has been added. No evidence of microbial growth in the durable compounds has been observed in the laboratory as was the case for the removable version.

c. Advances in pigment technology suggest that Ferro Green K-639 should be replaced with Ferro Green IE-670. The overall pigment concentrations have been increased, mainly to improve the hiding power in the infrared. Antimony sulfide has been removed as a black pigment because its stability is inadequate both in storage and in use. These actions required a general colorant reformulation for all four colors.

The formulations described in Table 7 have been made in small quantity and applied by brush to a nylon fabric used for another purpose. Field testing of the colored item proved entirely satisfactory despite very rough handling that challenged the adhesion of the recoloring formulations. Inspection in the laboratory, however, suggests a further reduction in gloss may be indicated.

It is believed that the Exploratory Development phase of the effort on the durable version of recoloring systems is essentially complete. Some further reduction in gloss is needed, but this is regarded as a rather minor matter. A draft Letter of Agreement has been forwarded to the Training and Doctrine Command for review. Should it be determined that a military need exists for a durable recoloring system, further effort will be scheduled in Advanced Development. Since several corrective actions are needed for the removable version, these will continue to be pursued under Exploratory Development.

TABLE 7. MODIFIED FORMULATIONS FOR DURABLE OVERCOLORANTS (percent)

	Light Green	Dark Green	Dark Brown	Black
Chlorinated Rubber 10 cps (Parlon S-10)	15.45	15.45	15.45	15.45
Chlorinated Paraffin Plasticiser(Chlorowax 40)	12.73	12.73	12.73	12.73
Solvent(n-butyl acetate)	40.91	40.91	40.91	40.91
"Flatting" Agent(Celite 110)	9.09	9.09	9.09	9.09
Organic Thixotrope (Thixatrol ST)	1.36	1.36	1.36	1.36
Epichlorohydrin (Gelatinn Stabiliser)	0.18	0.18	0.18	0.18
Epoxy Resin (Epon 828) (Heat Stabiliser)	0.54	0.54	0.54	0.54
Mildew Inhibitor				
Micro-chek 15	0.91	0.91	0.91	0.91
Zinc Oxide	0.64	0.64	0.64	0.64
		Pigments		
Ferro Green IE-670	6.73	14.0		
Ferro Yellow V-9112	11.27	3.82	8.36	
Ferro Red F-7195	0.18	0.36	2.73	
Carbon Black			1.36	3.6
Iron Oxide Black			5.45	14.55

General Procedure

(A) Dissolve Parlon S-10 in n-butyl acetate; Stir in Celite 110, Thixatrol ST, Epichlorhydrin, Epon 828.

(B) Grind (3-roll mill) all pigments, Micro-chek 15, and zinc oxide together with Chlorowax 40.
Stir B into A.